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ABSTRACT

This report discusses research and theory that explore relationships between comprehension and knowledge acquisition. Studies are reported that indicate the lack of a one-to-one correspondence between initial comprehension activities and abilities to remember. It is noted that the value of comprehensive activities depends on how people must later use the information. The concept of "transfer appropriate processing" is suggested as an alternative to the more one-sided concept of "depth of processing" that characterizes much current research. Subsequent discussion focuses more directly on problems of knowledge acquisition. Learning is distinguished from the storage and retrieval of memories, and the problem of coming to think "in terms of" information or "know with" information is discussed. A framework is proposed that focuses on processes of growth and transfer (processes by which one comes to understand things he or she could not previously understand). Empirical results are presented and potential educational implications are discussed. (Author/FL)

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FINAL REPORT

GRANT NO. NEG-00-3-0026

THE ROLE OF "EFFORT AFTER MEANING" AND "CLICK OF COMPREHENSION" IN RECALL OF SENTENCES

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I. Overview

The basic purpose of the research supported by the present grant was to investigate relationships between comprehension and knowledge acquisition. In particular, our research was directed toward exploring how "effort after (i.e., in the pursuit of) meaning" (cf. Bartlett, 1932) and the "click of comprehension" (cf. Brown, 1958) influence an individual's ability to learn from and remember the inputs to which he is exposed. Our initial research focused on the relationship between what people already knew and what they could effectively learn. Obviously, if inputs are unrelated to a person's current knowledge, he would be unable to achieve a click of comprehension--and hence be unable to effectively learn the material (e.g., Bransford & Johnson, 1972, 1973; Bransford & McCarrell, 1974). Our research therefore focused on the range of conditions where a "click of comprehension" was eventually possible. This range could extend from situations where one immediately comprehends inputs to conditions where considerable effort might be required to grasp the meaning of an input. We reasoned that inputs in the "difficult" portions of the range required a comprehender to reorganize aspects of his current knowledge. This reorganization should result in a greater degree of learning and hence facilitate recall. An exploration of activities leading to a reorganization of what one already knows as well as an examination of their effects on subsequent learning and remembering, constitutes a general theme underlying the research to be reported.

The present review is organized into two stages or phases. Stage I represents initial theoretical and empirical work that follows relatively directly from our grant proposal. Stage II represents a theoretical reformulation of certain assumptions inherent in our original proposal (as well as in much of cognition psychology), and the creation of new experimental paradigms for exploring the development of expertise in various domains.

II. Stage I of Research Activities

During the first stage of work on the grant, our research took two directions: (a) We investigated conditions of comprehension that appeared to produce flexible (and non-normative) understanding, and (b) We studied the relationship between conditions of comprehension and subjects' ability to remember what they understood.

A. Studies of comprehension flexibility.

(1) One sequence of studies (Barclay, Bransford, Franks, McCarrell, & Nitsch, 1974; Nitsch, 1974; Nitsch, McCarrell, Bransford, Franks, & Barclay, 1974) investigated the flexibility of the understood meanings of non-homonymous nouns (e.g., piano). These studies produced evidence that the understood meaning of such words varied with their sentential context. The method employed was to assess what functioned as an effective retrieval cue. For example, given the acquisition sentence The man lifted the piano, "something heavy" was more effective than "something with a nice sound" as a cue for recalling piano. The relative effectiveness of these two retrieval cues was reversed, however, if the sentence subjects heard at acquisition was The man tuned the piano.

This study demonstrated that language comprehension was indeed a contextually influenced process. More explicitly, it pointed out the inadequacy of the assumption that "meanings" are fixed entities stored in an internal dictionary, and that comprehension simply involves the selection and amalgamation of the appropriate subsets of meanings from this "dictionary entry." Further studies (i.e., Experiments III and IV in Barclay, Bransford, Franks, McCarrell, & Nitsch, 1974) showed that at the time of the memory test, subjects must reinterpret the target nouns (e.g., piano) in a manner congruent with their original interpretation during acquisition in order for the word to function as an effective retrieval cue for the acquisition sentence which they had heard. So, subjects hearing the acquisition sentence The man lifted the piano were effectively cued by the sentence "Pianos are heavy." They were much less apt to correctly recall this acquisition sentence when the retrieval cue was "Pianos have a nice sound." Naturally, the relative efficiency of these two retrieval cues was reversed for subjects hearing the acquisition sentence The man tuned the piano. The necessity of recreating the original interpretation of a stimulus in order for it to serve as an effective retrieval cue is further explored in studies to be described in Section B of Stage I.

(2) Subsequent studies by McCarrell, Nitsch, and Towler (1974) investigated the notion of flexibility as instantiated in an imagery task. These studies produced evidence that images of certain nouns reflected differential articulations (similar to the different interpretations of the "meaning" of the nouns in the preceding flexibility studies) depending upon the linguistically conveyed event in which they occurred. Subjects were given one of two lists of acquisition phrases with the instructions to form a visual image of each phrase and rank the vividness of this image on a 7-point scale. For example, one acquisition list contained An elephant squirting a zebra while the other list contained the phrase An elephant squashing an orange. Following acquisition, subjects were presented with retrieval cues and asked to recall the phrase in which the cue noun had occurred at acquisition. The retrieval cue "an elephant with a raised trunk" was more effective for subjects who heard An elephant squirting a zebra than was the cue "an elephant with huge legs." Relative cue effectiveness was reversed for subjects hearing the acquisition phrase An elephant squashing an orange.

These results support the hypothesis that subjects do articulate different types of information in their image of an entity. The visual information articulated in an image appears to vary with the context or the linguistically conveyed event in which it occurs. During recall, subjects must articulate this same information in order to effectively recall the phrase. These results suggest that we might fruitfully turn our investigations from the consequences of "having an image" to investigations of the processes which guide the generation of an image.

(3) Bransford and Barclay (manuscript in preparation) investigated a related aspect of the notion of semantic flexibility. Subjects were given

a reaction time task in which they were required to decide whether a particular target sentence was true or false. Each target or test sentence was immediately preceded by a priming sentence. Bransford and Barclay found the same results as were reported in the previously discussed results of Barclay, Bransford, Franks, McCarrell, and Nitsch (1974). For example, the priming sentence "The man carried the suitcase" produced significantly faster reaction times for verifying the target sentence Suitcases have handles than did the priming sentence "The man packed the suitcase."

(4) Another study (Franks & Bransford, 1974a) looked at the flexibility of recalling syntactic form as a function of semantic context. Slobin (1966) had found a much higher degree of verbatim recall for sentences in short passive form (e.g., The floor was washed) than in full passive form (e.g., The floor was washed by the janitor). Franks and Bransford (1974a) replicated this finding (using a recognition measure) for short passives for which no actor was supplied by extra-sentential semantic context. However, when extra-sentential context supplied information about the actor, verbatim memory for the short passives was greatly reduced, and subjects tended to recognize alternate sentential forms (actives and full passives) expressing the meaning of the short passives but including contextually given actors.

(5) Finally, a theoretical chapter (Bransford, McCarrell, & Nitsch, 1976) discussed the failure of normative theories (associative theories, feature theories, conceptual category theories, imagery theories, linguistic theories of selection restrictions, etc.) to adequately account for a wide range of the situations in which linguistic comprehension normally occurs. In particular, this chapter considered the issues raised by the previously described studies of semantic flexibility. Rather than equating comprehension with "grasping the meaning" of a word (e.g., paper), comprehension was discussed as involving an appreciation of the intended significance of the usage of a word. Thus, a listener uses his knowledge of a word's meaning to understand the significance of a speaker's utterance, and this significance varies as a function of context. These authors point out that one cannot even assume that "sentences are already meaningful" as Lesgold, Curtis, Degood, Golinkoff, McCormick, and Shimron (1974) do. The concept of significances is just as important at the level of sentences as it is for individual words. Within the realm of non-linguistic comprehension (e.g., gestures), the concept of significances is relevant as well (see Bransford & McCarrell, 1974; Brewer, 1974; Franks, 1974).

(6) Issues relating to semantic flexibility and significances suggested the need for a closer scrutiny of the general problem of meaning. A paper by one of our students (Nitsch, 1975) considered aspects of this issue and further discussed implications of the concept of significances and the notion that lexical meaning serves as a "tool" which the comprehender uses in order to comprehend (cf. Fillmore, 1971; Wittgenstein, 1953). This paper provides an important basis for developments to be discussed in Phase II.

B. Relationship between conditions of comprehension and subjects' abilities to remember what they understood:

The studies to be discussed in this section explore somewhat different aspects of the question of what kinds of activities take one beyond his normative knowledge and help him learn (i.e., facilitate growth). Practice and exposure are frequently claimed to be the major variables underlying learning and skill acquisition (e.g., Chase & Simon, 1973). However, a mere emphasis on practice and exposure is not sufficient. This ignores the question of which exposures or practices are most helpful. Furthermore, this does not help one understand what learners must do in order to make exposures maximally effective.

(1) A set of studies conducted by Nitsch, McCarrell, Franks, and Bransford (manuscript in preparation, and see Bransford, Nitsch, & Franks, in press), was designed to investigate the preconditions for achieving "expertise" at imaging a particular situation given equivalent amounts of exposure. All subjects in the experiments were given a one-minute exposure to a colored picture of a living room, but were given different orienting tasks. Group I was told that the picture contained from 0 to 3 inked in X's. Their task was to scan the picture first horizontally, then vertically, then horizontally, etc. When told to stop they were to report the number of X's they had found. Group II was given the same instructions, except that they were told that all X's were in contour of objects. They therefore searched contours until told to stop. Group III was told that we were interested in the types of actions that they might perform on the objects in the living room. They expected to report only on actions they generated and not on the visual layout of the room. Group IV was given intentional recall instructions: Study the picture with the intent of recalling the objects and relative locations of the objects that it contained. Following the one minute exposure, all subjects were given a surprise recall test (of course, the test was no surprise for Group IV) in which they indicated the relative position of the objects from the picture on a recall sheet.

The results were quite dramatic. There were non-overlapping distributions between Groups I and II vs. III and IV. Groups I and II recalled and located from 3 to 8 objects. The range for Groups III and IV was from 25 to 32. Following free recall all subjects were presented with probes such as "Was there a window (and where)?", "Was there a wine glass (and where)?", etc. Even when given these cued recall probes, the non-overlapping distributions of recall scores persisted. Subsequent analysis indicated that the cued recall increment over free recall scores was about three items for subjects in all of the four groups.

The x-scanning results indicate that differences in performance cannot merely be due to the amount of exposure. What is important is exposure in relation to the activities that subjects perform. Given a certain criterion task (in this case a recall test), certain activities are more fruitful than others for performance on that task.

(2) Bransford, Franks, McCarrell, & Nitsch (manuscript in preparation) designed a series of studies to investigate more directly the influence of different types of comprehension activities (i.e., "effort after meaning")

upon free and cued recall performance. Subjects in the first study were asked to rate a list of 24 relatively concrete, imageable sentences on a 7-point imagery scale. Two types of sentences were randomly ordered in this acquisition list: (a) 12 sentences that were relatively easy to comprehend and image ("Easy" sentences, e.g., An umbrella has spokes), and (b) 12 sentences that were more difficult to comprehend and image ("Difficult" sentences, e.g., A knife can be used as a screwdriver).

Following acquisition, incidental learning was assessed as subjects were asked for free recall of the acquisition sentences. Following free recall, subjects were then provided with the subject nouns of each of the acquisition sentences as retrieval cues and asked to write down the predicate of each sentence. Results from the free recall measure indicated that subjects recalled significantly more "Difficult" sentences than "Easy" sentences. However, cued recall scores reflected the reverse trend: "Easy" sentences were more frequently recalled than "Difficult" sentences.

In a second study, two lists of acquisition sentences were employed. One list was comprised of 24 "Easy" sentences and the second list contained 24 "Difficult" sentences. Two groups of subjects were given the same acquisition and memory tasks as in the first experiment; one group heard only "Easy" sentences and the other heard "Difficult" sentences at acquisition. This time the recall results showed no memory differences between "Difficult" and "Easy" sentences for either free or cued recall. Thus, the difference between memory for "Easy" and "Difficult" sentences was apparent in a within-subjects design but did not hold in a between-subjects comparison. These results seemed to indicate that subjects in the two experiments had employed different retrieval schemes depending upon the nature of the acquisition list they had heard. This supposition led us to investigate more closely the relationship between initial comprehension and the nature of the memory test.

(3) In a series of studies examining this relationship between comprehension and memory, Nesbitt (1974) used easy and difficult to solve similes as stimulus materials. In his first study, Nesbitt compiled a list of easy to solve similes (e.g., a pencil is like a nail) and difficult to solve similes (e.g., an eraser is like a magician). On acquisition, subjects were read this list and were asked to judge for each simile whether or not they found a relation between the two nouns in the simile--"yes" or "no." Afterwards subjects were asked to free recall as many of the acquisition similes as possible. The free recall results showed that a higher proportion of "Difficult" similes were recalled. A separate analysis also revealed that similes rated as comprehensible (i.e., "yes") were more likely to be recalled than those rated "no" on acquisition. Thus, both "effort after meaning" and the "click of comprehension" were shown to have facilitory effects upon free recall performance.

When these subjects were then tested with a cued recall task, the results were reversed. "Easy" similes were better in cued recall performance than "Difficult" similes. However, equivalent cued recall performance was

found when "Easy" similes which were rated by subjects at acquisition as comprehensible (i.e., those receiving "yes" judgments) were compared only with the "Difficult" similes which were rated as comprehensible. A third measure, recognition memory, was also assessed for these subjects. Recognition scores were equivalent for both classes of similes ("Easy" and "Difficult") and for both comprehensible and incomprehensible similes (as rated by each subject).

Thus a very complex pattern of results appeared, indicating that the "best learned" kind of acquisition similes (easy vs. difficult, comprehensible vs. incomprehensible) could not be unequivocably identified--one must first specify the type of retention measure to be used as a criterion for "goodness" of learning. For example, Difficult similes fostered better free recall performance, while in cued recall Easy similes were superior to Difficults. A recognition measure gave no indication of any differences among kinds of acquisition items.

In order to further investigate these results, Nesbitt conducted a second study in which subjects were provided with a solution along with each acquisition simile (e.g., A pencil is like a nail because both are long and pointed or An eraser is like a magician because both make things disappear). Subjects were asked to rate each acquisition item as "Yes" (meaning it expressed a good solution) or "No" (meaning it did not express a good solution).

Under these acquisition conditions, free recall performance was equivalent for both Easy and Difficult similes. For cued recall, Easy similes were better remembered than Difficult similes. This difference was also true even when only Easy and Difficult similes which were rated "Yes" were compared. Once again, recognition performance was equivalent for both acquisition types.

What emerges from the complicated results of these two studies goes beyond a simple statement that "goodness" of memory depends upon testing conditions as well as acquisition conditions. It appears that creating a relationship (i.e., actually solving the similes as subjects in Experiment I did) facilitates the recreation of the appropriate interpretation of an item at the time of test. Recall that the necessity to recreate one's original interpretation of an acquisition item at the time of test in order for it to serve as an effective retrieval cue was also demonstrated in Experiments III and IV of the semantic flexibility studies discussed in Section II A (1) (see Barclay, Bransford, Franks, McCarrell, & Nitsch, 1974). This same effect was demonstrated here: Difficult (i.e., non-normative) items which a subject in Experiment I had comprehended were equally likely to serve as effective retrieval cues as were the Easy (i.e., normatively comprehended) items. In Experiment II, where the subjects were not allowed to create their own solutions, this result did not hold: Easy similes were better cued recalled than were Difficult ones.

In general, Nesbitt's studies show that there is not a one-to-one correspondence between comprehension and memory. Performance on a memory

task was seen to be dependent upon the nature of the retrieval cues available to the subject. Therefore, we looked more closely at the issue of retrieval cue effectiveness. For example, one constraint on effectiveness seems to be that there is an "optimal number of items" associated with a category or cue (Mandler, 1967).

(4) A study by Bransford and Nitsch (manuscript in preparation, and see Bransford, McCarrell, Franks, & Nitsch, in press) instantiated some intuitively obvious constraints on remembering. In particular, the study attempted to show that: (1) certain hypothesized structures of storage may "explain" one type of memory performance (e.g., free recall) but fail to explain another type (e.g., cued recall); (2) various cued recall probes permit subjects to "gain access" to different parts of hypothesized stored structures, hence there are variable points of "entry" into such structures; (3) there are definite constraints on cue effectiveness; in particular, constraints on the number of items that can be "associated" with a particular cue.

Three different groups of subjects heard twenty-eight acquisition sentences. All groups heard the same predicates (e.g., tuning a violin, catching a ball, etc.), only the subject nouns were changed. Group 28 heard twenty-eight distinct subject nouns. Group 7 heard seven different subject nouns with four predicates for each subject noun (i.e., they heard four sentences about a boy, four about a policeman, four about a truck, etc., and these were blocked during acquisition). For Group 1, all twenty-eight sentences were about a single topic, i.e., a boy. Subjects were asked to image each sentence during acquisition (e.g., "image a boy tuning a violin"). Following acquisition they were asked to free recall.

Free recall results indicated that Group 7 was superior to 28 and 1. Group 1 exhibited the lowest recall. Such results parallel what would be expected given assumptions about benefits of categorization along with assumptions about the optimal number of items per category. For example, subjects in Group 7 could be expected to have "stored" the sentences in seven different categories and to have searched these categories. Indeed, their recall protocalls were clustered in terms of the categories they had heard. However, by this logic, subjects in Group 1 would have heard too many members of a single category, hence their ability to recall was limited.

Following free recall, all subjects were given probes to aid them in retrieval. One-half of the subjects in each group received the subject nouns as retrieval cues and the other half received the object nouns. The results were scored in terms of correct verb recall in order to compensate for the different numbers of subject nouns each group heard. Under subject-noun cueing conditions, Group 28 exhibited the best performance, Group 7 was second, and Group 1 was the worst. In fact, Group 1 showed no improvement between free and cued recall. However, under object-noun cueing conditions, all three groups exhibited equivalent performances. These results (especially considering Group 1) indicate that the problem of the optimal number of items per category is not a limitation of storage. Could it be a limitation on search?

Assume that the input sentences were stored in different organizational structures for the three different groups of subjects: Group 28 subjects "stored" each sentence individually, those in Group 7 stored them in terms of seven different categories, and Group 1 subjects stored them all under one category. How did the presentation of retrieval cues help subjects augment their recall? For example, when subjects received the object-nouns as cues, did they then have to search through their various stored organizational structures in order to "find" the proposition containing the object noun? If they did, then why couldn't they simply search and find that proposition under other recall conditions as well? It was assumed that subjects in Group 7 stored the sentences in terms of seven categories organized by subject nouns and searched through these in free recall. Did these subjects have to search through these same categories when given the object nouns as cues? This seems highly unlikely given that their recall cued by object nouns was superior to recall cued by subject nouns. Why should subjects be able to effectively search for items containing the appropriate object nouns, yet fail to search as effectively for items containing the subject nouns? Similar arguments can be made about the performance of Group 1 subjects: If subjects had to search to find a proposition containing a particular object noun, why couldn't they search just as well when given the subject noun as a cue?

The above results suggest that the presentation of cues allowed subjects to somehow "modify their search processes." However the ability to "know where to look" presupposes some knowledge of "where things are likely to be stored." In addition, if one postulates the existence of certain "stored organizational structures" on the basis of free recall performance then it would appear that the presentation of recall cues somehow allowed subjects to "bypass" such structures. Perhaps the notion that inputs are "organized and stored together" is also an unfruitful metaphor. One might alternatively view performance in free recall as depending on the implicit generation of retrieval cues (Tulving, 1974). The organization postulated on the basis of free recall performance would therefore not necessarily reflect the "structure of storage" as much as it reflects the availability of the implicit cues that subjects themselves use.

The Bransford and Nitsch study argues that the presentation of probes appeared to allow subjects to "bypass" hypothetical stored organizational structures. In addition, the study documents an intuitively obvious constraint on cue effectiveness: The cue "a boy" was much more effective for helping subjects recreate the appropriate acquisition experience if they had heard only one sentence about a boy rather than 28 "boy" sentences. An effective retrieval cue must allow one to unambiguously differentiate among previous experiences he has had.

(5) One of our students, Barry Stein (cf. Bransford, McCarrell, Franks, & Nitsch, in press) has conducted a number of retrieval studies which further consider the problem of differentiation or uniqueness. His studies extend Nesbitt's (1974) work on similes. In Stein's studies, typical similes might be A pin is like a nail; A bumper is like a statue; A pliers is like a crab, etc.

During acquisition, subjects in Group I were simply asked to indicate the ease with which they could "solve" each of a list of 24 similes. Group II heard the same similes in the same order, however, they were asked to rate whether the two items in each simile were relatively the same or different on a hardness-softness scale. Following acquisition, the subjects in both groups were given the subject nouns as retrieval cues and asked to recall the second member of each pair. Recall results indicated that Group II subjects performed far below Group I subjects--21% vs. 59%.

It is instructive to note that in subsequent studies Stein found no differences between Groups I and II on recognition for individual subject and object nouns. The groups differed slightly in their abilities to recognize appropriate and inappropriate pairings of previous acquisition items, but the differences were not nearly large enough to account for the magnitude of the differences in cued recall. What might account for this large decrement in Group II's cued recall?

Note that the "retrieval" problem in Stein's study is not one of "finding" the "stored stimulus item" given a retrieval probe. Instead the problem is one of being able to "follow the connection" between the first and second member of each pair and there was only one "connection" attached to each individual subject noun. Does the ability to remember depend on "finding" or following" connections, or on something else?

For Group I, each simile was presumably solved in a relatively unique manner. To solve a simile such as A pin is like a nail, one must interpret "pin" in a particular manner (e.g., one may focus on the fact that it is long and pointed). Given the probe "a pin," it seems reasonable to assume that subjects must recreate their original experiences (which would include focusing on a pin's pointedness, etc.). This latter information would then uniquely specify another experience involving pointedness (i.e., a nail), hence cued recall would be relatively good. However, for Group II, the experiences generated by a probe like "a pin" would involve a respecification of its relative hardness. A host of other items on the list were also thought of in terms of their hardness, hence this information would not be sufficient to accurately recreate the appropriate item from each pair. Viewed from this perspective, Group II in the Stein study is functionally equivalent to Group III in the Bransford and Nitsch study (where subjects heard all sentences about "a boy" and received "boy" as a retrieval cue). In the Stein study, subjects have essentially been provided with the same functional cues for a large number of different events.

(6) Bransford, Nitsch, McCarrell, and Towler (manuscript in preparation) conducted a series of studies which also investigated relationships among acquisition activities and retrieval. They compared recognition and cued recall performance for noun triads learned under two different contextual conditions. Context was manipulated by varying the organization of the triads in the lists. In one list each triad contained one abstract noun and two concrete nouns which together comprised a meaningful group (e.g., enterprise-lemonade-sidewalk, fallacy-stork-baby). In the second list the abstract nouns

from the triads were randomly paired with concrete noun pairs (e.g., jeopardy-lemonade-sidewalk, confidence-stork-baby).

One group of subjects heard the meaningful list and another group heard the random list. All subjects were asked to listen to each group of nouns and were told that they would be asked something about the nouns later. Following acquisition both groups were given a list of the 25 abstract nouns in the acquisition list and 25 new abstract noun foils arranged in a random order. Subjects were asked to indicate which items they had heard in the acquisition list and to rate each on a 5-point confidence scale. Subsequent to the recognition test, subjects were given a cued recall test in which they were to supply the concrete noun pairs which occurred at acquisition in the triad with each of the 25 abstract nouns.

Analysis indicated that the organization of the meaningful triads facilitated overall recognition rate and depressed false positive rate relative to the random list. Organization also facilitated cued recall. Data derived from confidence ratings revealed a strong positive relationship between confidence of an item's positive recognition and the probability of its being an effective cue for recall. In fact, subjects reported that during recognition they had tried to recreate the original acquisition triad to aid in their recognition task.

In order to investigate further the relationship between recognition and cued recall, an analysis was performed only on those recognition items which were <u>not</u> effective cues for recall. On these items, the recognition of the random group was actually <u>higher</u> than that of the organized group. This latter trend suggested that organization might sometimes debilitate recognition performance if (a) subjects must recreate the encoded global event to recognize it effectively and (b) a particular word to be recognized is not an effective cue for recreating that event. The emphasis here is on the encoded event. When subjects in the random group receive each noun-triad, they are less likely to encode the three nouns as a single related event. In fact they may encode them as three separate items. If so, they will be much less penalized by a failure to recall than will the meaningful group because the recognition item will get them back to the event they encoded, i.e., a single item.

This possibility was tested in the second experiment. The same stimuli were used. The only difference was that the subjects were asked to recognize the second rather than the first member of each triad (i.e., a concrete noun rather than an abstract noun). Previous research (Bransford & McCarrell, 1974) indicated that the second member of a triad was a less effective retrieval cue than the first member. If subjects in the meaningful group in the first experiment showed superior recognition because of the advantage in recreating the total encoded acquisition event, the subjects in the same group in the second experiment should show less of an overall advantage. The important prediction, then, is that the random group should show superior performance on items that are recognized but elicit no cued recall response.

Acquisition, recognition, and cued recall procedures were identical to those of the first experiment. (Except during recognition, subjects were given a list of 50 concrete nouns, and during cued recall, subjects were presented with a concrete noun cue and asked to recall the other two nouns, i.e., one concrete noun and one abstract noun.) Analyses indicated that subjects in the random group did demonstrate significantly better overall recognition performance as well as a significantly higher recognition rate for those nouns which later elicited no cued recall response.

These results also confirmed our previous belief that the retrieval process seems to be dependent upon the context or the total set to which a particular item belongs. Although the meaningful group performed worse on the recognition task, they recalled more noun-pairs than the random group. The results from the recognition task and the recall task together suggest that encoding a triad as a total event, while tending to help on a cued recall task, can be detrimental to performance on a recognition task.

(7) The notion that remembering is a function of the total set to which an item belongs was further explored by Franks and Bransford (1974b). They note that subjects in a semantic integration paradigm have difficulty distinguishing between OLD and NEW sentences (Bransford & Franks, 1971). Yet there is some ability to differentiate among these items; especially at the level of ONES, i.e., sentences containing only one proposition (e.g., see Bransford & Franks, 1971; Anderson & Bower, 1973, p. 350-351). However, a re-analysis of the OLD-NEW data from Bransford and Franks (1971, Experiment III) indicates that only certain ONES contribute to this difference. This re-analysis (Franks & Bransford, 1974b) was motivated by Singer and Rosenberg's (1974) findings that subjects' "yes" responses to test sentences were strongly affected by the presence or absence of the main clause of the overall events.

The ONE sentences from Bransford and Franks (1971, Experiment III) were partitioned into those that did and did not contain the main clause of the events acquired during acquisition. For example, the ONE The rock crushed the hut was assumed to express the main clause of the FOUR The rock which rolled down the mountain crushed the tiny hut at the edge of the woods. Results indicated that there was no difference between OLD and NEW ONES that contained the main clause (percent yes ratings were 37.3% and 34.6% for OLDS and NEWS respectively). There was, however, a marked difference between ratings for OLD and NEW ONES that did not contain the main clause (percent yes ratings were 36.4% and 17.7% for OLDS and NEWS respectively).

Consider these results in connection with the fact that a completely unique sentence embedded in a semantic integration paradigm is extremely well recognized. If subjects are listening to a set of semantically related acquisition sentences and hear a ONE like The hut was tiny, at least some of them may perceive it as unrelated to any previous experiences. Lack of information about the main clause may prompt subjects to perceive such ONES as unique. During recognition, these subjects should therefore recognize such particular utterances, hence there should be overall recognition differences depending on whether such ONES were OLD or NEW. On the other hand, ONES with main

clauses should be less likely to be perceived as unique during acquisition. Therefore, ONES with main clauses would be expected to receive equivalent ratings whether they were OLD or NEW.

The preceding discussion indicates that the important issue with respect to memory is not whether people are always accurate or inaccurate in their abilities to remember. Instead, the issue involves the conditions under which subjects can recreate previous experiences they have had. One can, of course, concentrate on accuracies and assume that inaccuracies are due to "errors," "confusion," "interference," etc. On the other hand, one can focus on the acquisition of global, invariant information as a function of a total set of acquisition experiences. The information derived from the total set of acquisition experiences sets constraints on one's abilities to recreate previous acquisition experiences (i.e., remember). In short, it appears that what is learned cannot simply be equated with a list of previous memories. In fact, it would appear to be the global nature of what was learned that sets constraints on one's abilities to recreate (i.e., remember) those inputs experienced during the acquisition task.

(8) Overall, the studies discussed previously suggest that there is no simple one-to-one relationship between certain comprehension activities and one's ability to remember. Instead, the "goodness" of processing must be defined relative to test conditions. This theme was pursued in a paper written by one of our students (Morris, 1976). He reviewed the "levels of processing" literature and discussed the theoretical problems associated with its "goodness of memory" assumption. Morris proposed the alternative that one should consider "transfer appropriate processing," a more flexible concept than the static notion of "depth of processing."

As an example, consider a "levels of processing" experiment conducted by a number of us at Vanderbilt (i.e., Morris, V. Franks, Stein, J. Franks, and Bransford and see Bransford, Nitsch, & Franks, in press). In a within-S design, subjects either had to decide whether an acquisition target word rhymed with a preceding word (rhyme acquisition) or fit meaningfully into a sentence frame (semantic acquisition). A recognition test indicated that semantic processing produced superior recognition to rhyming processing (hence replicating results from Craik & Tulving, 1975). It is therefore easy to assume that semantic processing results in "better" memory. But better for what?

A second group of subjects received the identical acquisition list but a different type of test. They were presented with a completely novel group of words at recognition and asked to decide which ones rhymed with the acquisition stimuli. Under these conditions, the subjects were better at recognizing rhymes of acquisition words that had initially been processed in a rhyming rather than a semantic mode. The "goodness" of memory resulting from different acquisition activities is therefore relative to the subsequent activities that one wants subjects to perform. A memory expert who realized that his task would be similar to that of Group II (rhyme recognition) would

surely choose a "less meaningful" mode of processing (i.e., auditory rather than semantic) the acquisition stimuli. The expert would determine the nature of the total task and gear his acquisition activities to the nature of the test.

As another example of "transfer appropriate processing," consider the pictures in Figure 1 (a) and (b). Which one might a memory expert choose

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Insert Figure 1 (a) and (b) here

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to study during acquisition? As is well known in the imagery literature (e.g., see Paivio, 1971), coherent scenes (like Figure 1 (a)) are much better recalled than jumbled scenes. Are coherent ("meaningful") scenes therefore better for all types of memory tasks? A recent study by McCarrell, Nitsch, and Bransford (manuscript in preparation, and see Bransford, Nitsch, & Franks, in press) illustrates that the value of particular acquisition conditions depends on the nature of the test. The subjects saw either Figure 1 (a) or (b) for 90 seconds with the instruction to study the inputs because they would later be asked to remember what they had seen. Following acquisition, all subjects were presented with information like that depicted in Figure 2 and asked to decide which member of each pair of elements they had actually seen.

Insert Figure 2 here

Those subjects who had seen the jumbled elements (Figure 1 (b)) were far superior to subjects who had studied the coherent scene. Clearly the most successful strategy a learner could have would be to choose the optimal acquisition conditions and activities as a function of the particular type of test to be used in measuring transfer. Such a strategy would by necessity be extremely flexible. Knowledge of how information is to be used is essential for allowing one to learn in a manner most appropriate for a particular task.

III. Stage II

The research results discussed in Stage I indicated complex interactions among initial comprehension activities and the nature of the memory test. These findings led to a more careful examination of comprehension and learning from the perspective of transfer. Various memory tests (e.g., recognition, cued recall, free recall) can be viewed as transfer tasks, and particular acquisition activities may be helpful or harmful depending on the requirements of the testing situation. However, it became clear to us that there are types of transfer that are not readily assessable by any of these memory measures. For example, certain types of acquisition experiences may prepare one to understand and learn subsequently presented new materials more efficiently. Development of this type of expertise is clearly a major goal for education. It seemed possible that those initial acquisition activities that might be most effective for <u>remembering</u> could actually hinder one's abilities to <u>transfer</u> to new situations. Our original grant proposal purported to study relation-

ships between comprehension and knowledge acquisition, yet all our proposed studies had employed memory measures. We therefore set out to reconceptualize the problem of knowledge acquisition and to develop a potentially more fruitful experimental approach.

Beginning in the second year of our grant period, members of our laboratory held numerous theoretical discussions and exchanged thought papers on problems of learning or knowledge acquisition. While questions about learning still flourish in the animal literature, it seemed that cognitive psychologists had tended to tacitly equate learning with the formation and storage of "memories." Tulving (1972) had distinguished between "episodic" and "semantic" memory, but even research in the latter area did not ask how "semantic"knowledge could be acquired effectively. One of our students (Hannigan, 1975) reviewed the semantic memory literature and raised questions about the ability of various models to account for "semantic flexibility" (e.g., Barclay, Bransford, Franks, McCarrell, & Nitsch, 1974; Bransford, McCarrell, & Nitsch, 1976; Nitsch, 1975) as well as the problems of initial acquisition. Literature reviews, discussion, and thought papers resulted in a reconceptualization of the problem of learning that to date has resulted in five book chapters (published in various volumes) plus the development of new experimental paradigms for exploring problems of learning (or growth) and transfer. Some of these initial ideas were incorporated into the N.I.E. planning session (1975) on the nature of reading and directions for reading research (see especially section 2.4 on "Knowledge, Growth and Use" and note the emphasis placed on this section in the general discussion of the report). The developments which led to the present conceptualization of the problem of growth are outlined below.

A. The "Toward Unexplaining Memory" chapter.

Bransford, McCarrell, Franks, and Nitsch (in press) attempt to differentiate the problem of learning from the problems of how one forms and stores "memories." As an example, they discuss the problem of learning to play tennis. As Bartlett (1932) noted, one does not learn particular responses, nor connections between responses and stimulus situations (e.g., connections between a particular response and the stimulus of a tennis ball coming over the net and bouncing in the right-hand corner of the court). Previous experience allows the creation of more finely tuned "novel but appropriate" acts (e.g., see Bernstein, 1967; Green, 1971; Turvey, in press). But note that questions about tennis playing ability are not equivalent to questions normally asked when remembering is studied in the laboratory. The type of question asked in memory experiments is more equivalent to "Try to reproduce those exact strokes that you just made" or "Describe the places where the ball hit during your last volley."

It seems possible that a tennis player, for example, might be relatively accurate at answering the latter questions. And it might be argued that the ability to do so depends on stored "memories" of previous experiences. But even granting (for the moment) this "memory" assumption, one surely would not wish to simply equate the ability to play tennis with a list of previous memories of tennis playing experiences. Such an equation seems as implausible as equating one's "knowledge of his native language" with a list of memories of previously experienced sentences or even paraphrases of these sentences (e.g., see Chomsky,

1965). One's ability to remember will undoubtedly be related to the nature of the knowledge acquired through learning, but it would seem strained to equate the problem of learning with the problem of how memories are stored and retrieved.

These authors also review various data on remembering and conclude that what is learned cannot be equated with the mere formation and storage of memories. Indeed, it is concluded that one's ability to adequately remember depends on the nature of what was initially learned. These conclusions are related to J. J. Gibson's (1966; in press) views of learning and to other chapters in a volume edited by Shaw and Bransford (in press a). The "Unexplaining Memory" chapter as well as much of the editing of other chapters in the volume were both begun and completed during the tenure of the present grant.

B. The "Psychological Approaches to the Problem of Knowledge" chapter.

A chapter by Shaw and Bransford (in press b) took a different approach to arguments about differences between learning and memory. This chapter argues for a "non-memory mediation" approach to perception as suggested by J. J. Gibson (1966; in press). The general conclusions are quite similar to those from the "Unexplaining Memory" chapter cited above. However, the nature of the arguments permit contact between our present position and many additional areas of theory and research.

C. The "Toward a Framework for Learning" chapter.

Based on the preceding chapters, Bransford and Franks (1976) attack problems of learning more directly. They focus on the novelty involved in transfer, and argue against the "memory metaphor" assumptions underlying most psychological theorizing and research. This chapter proposes a "stage setting" metaphor rather than a "memory" metaphor for viewing the effects of past experiences. The stage setting metaphor leads naturally into questions about the growth of knowledge, and this topic is discussed. It is argued that knowledge in a form that permits optimal remembering may not be in a form optimal for transfer. How can people be helped to acquire knowledge in a form that is useful for clarifying subsequent experiences they have? The chapter discusses the intuitively powerful process of exemplification as a means of helping people acquire knowledge in a form useful for transfer (see also Section 2.4 of N.I.E. document). Exemplification is discussed from a "non-memory metaphor" perspective, and the value of abstract knowledge is discussed.

The Bransford and Franks chapter also attempts to define the domain of theories of remembering and show how remembering depends on people's use of knowledge. In addition, theories of semantic memory are criticized because of their inability to characterize (a) the value of the abstractness (or flexibility in application) of knowledge and (b) the problems of growth.

D. "The Use of Embedded Questions in the Facilitation of Productive Learning."

Concurrent with the writing of the "Framework for Learning" chapter, a thesis by one of our students (Pollchik, 1975) explored the effects of examples on helping students learn from textual material and hence transfer to novel situations. This research resulted from Pollchik's (1974) previous review of reproductive vs. productive learning and on adjunct aids to learning (see also Anderson & Biddle, 1975). Pollchik's (1975) results indicate the extremely powerful effect of examples. More important, his data illustrates that the effectiveness of "adjunct aids" to learning interact with the structure of the text. These results play an important role in later chapters which attempt to sketch a theoretical framework for conceptualizing problems of growth (e.g., the chapter by Bransford & Nitsch, in press).

E. The "Schooling and the Facilitation of Knowing" chapter.

Bransford, Nitsch, and Franks (in press) discuss reasons why experimental research on learning and remembering may fail to provide insight into problems of education. They do not argue that experimental research is useless, but rather that psychologists need a theoretical framework for interpreting the meaning of research findings as well as for generating additional research.

The chapter focuses on problems of growth, and couches the discussion in terms of the development and maintenance of expertise in various domains of knowing. The orientation therefore focuses on the problem of learning what to do to go beyond one's present state of knowing. The authors contrast this orientation with those emphasizing episodic memory, semantic memory, and verbal learning principles. Some of these contrasts are sketched below.

Comparison with theories of episodic remembering: Few would deny that education involves something more than merely remembering. Despite this, the relationship between memory and the development of expertise (e.g., learning) is not necessarily clear. For example, it is frequently assumed that learning results in the formation of "traces" or "memories." Research on remembering might therefore be directly relevant to issues about learning, since remembering should be related to the degree to which one has learned. From this perspective, research on learning and remembering seem closely intertwined.

However, consider some contexts where emphases on learning and remembering are widely divergent. As noted earlier in this report, playing tennis represents a case in point. The problem of specifying what it means to learn to play tennis is very different from the typical concerns of the memory theorist. The latter is more likely to request his subjects to

"Remember the strokes you made during the last five minutes of the game," or "Remember where the ball bounced during the last three minutes." The problem of becoming a tennis expert seems clearly different from the problem of remembering what one just did (see Bransford, McCarrell, Franks, & Nitsch, in press; Bransford & Franks, 1966, for more detailed discussion of these points). Similarly, one can learn to become better and better at remembering; that is, one can become a "memory expert." However, one does not become a memory expert simply by memorizing a book about memory experts. Instead, one must learn how to use such information to carry out memorizing acts.

Comparison with theories of semantic memory: The fact that learning is not necessarily equivalent to remembering is often handled by appealing to "semantic" as opposed to "episodic" memories (Tulving, 1972). One may know something (e.g., an inference) following some experience like reading a passage, yet avoid the trap of falsely believing that he remembers explicitly experiencing that particular information (see Kintsch, 1974; Tzeng, 1975). If one assumes that knowing depends on semantic memory whereas remembering depends on contact with episodic memory, then theories concerned strictly with episodic memory are clearly inadequate to characterize all the processes involved in education.

However, our present emphasis on learning what to do in order to go beyond one's current level of clarity and understanding also differs from the problems addressed by most theories of semantic memory (e.g., Collins & Quillian, 1969; Freedman & Loftus, 1971; Loftus & Freedman, 1972, Meyer & Ellis, 1970; Meyer & Schvaneveldt, 1971; Rips, Shoben, & Smith, 1973; Smith, Shoben, & Rips, 1974). The latter attempt to account for the speed and ease of certain acts of knowing by making assumptions about the pre-existing structure of already acquired information. Their emphasis is more on describing how one can know given certain pre-existing structures than on discovering the processes by which certain "structures" might be formed (see Bransford & Franks, 1976, for a more detailed discussion of this problem).

As an example of semantic memory models, consider the fact that it is easier to verify that "A canary is yellow" than it is to verify that "A canary has skin." According to many models (e.g., Collins & Quillian, 1969), this is due to the fact that "yellowness" has been directly stored with canary, whereas "skin" has been stored with animals. One must therefore "search" longer in order to verify that a canary has skin. Similarly, it may be easier to verify that nurse and doctor are both words than to verify that nurse and butter are both words (e.g., Meyer, Schvaneveldt, & Ruddy, 1972). Prototypic explanations assert that the former two words are stored more "closely together" in semantic memory, hence "spreading activation" can more readily occur (e.g., Meyer, Schvaneveldt, & Ruddy, 1972; Loftus, 1973). Theories of semantic memory attempt to account for knowing solely on the basis of the structure of already acquired information. So-called "process" models of semantic memory are involved with explaining how to use already stored information in retrieving facts, making comparisons, etc. However, these

notions of "process" are not equivalent to the processes involved in the development of knowing. The latter involve discovering how to go beyond what is already known.

A simple example can help clarify the difference between semantic memory models and the present orientation. One could compare the ability of Einstein and a nonphysicist to solve a physics problem. The differences in their problem-solving abilities could be "accounted for" by assuming that Einstein already had knowledge about relativistic physics whereas the novice lacked such knowledge. Such an "account" would be equivalent to the form of most models of semantic memory. But note that the latter models provide no clues to the processes by which Einstein arrived at his knowledge of relativistic physics. The present orientation is most primarily concerned with this question. Models of semantic memory are at best paraphrases of the objects of our knowing activities (see Bransford & Franks, 1976, for further discussion). They fail to provide insights into the processes by which people learn what to do to go beyond what they know at a particular time.

Comparisons with "verbal learning" research: As a final contrast between the present orientation and others, consider the orientation of a number of "verbal learning" studies purporting to study meaningfulness. A host of studies document the intuitively obvious fact that meaningful material is more easily learned than less meaningful material. For example, Johnson, Doll, Bransford, and Lapinsky (1974) examined the effects of repetition on recall of anomalous sentences versus recall of these same sentences made meaningful by context manipulations. They found that repetition facilitated recall for meaningful sentences much more than recall for the anomalous sentences.

It is both interesting and important to ask why meaningfulness increases repetition effectiveness, but again this misses a crucial point. Most theories that attempt to explain why inputs perceived as meaningful are better learned deal with the products of previous acts of knowing at state 1, 2, 3, etc. In the above case, the products are divided into two classes: meaningful and anomalous. Explanations for the varying effectiveness of repetition typically attribute differential structural or normative characteristics to these products of previous knowing activities. The critical point such approaches neglect is the question of how one learns to do things to make inputs meaningful in the first place. How does one get from one state to another? With respect to the problem of experts, the question is not so much what they know, but how they became experts and how, as experts, they continue to go beyond their present state of knowing.

The paper proceeds to discuss aspects of the problem of expertise with theories assuming that learning simply involves amassing a storehouse of more and more knowledge. We ask how people can come to think "in terms of" or "know with" (cf. Broudy, in press) information rather than simply "know about" some topic. Growth is viewed as the "remodeling" of one's perspective rather than the accumulation of more and more facts or content. Pilot studies

conducted by Mary Lessick Hannigan (one of our students) are cited as providing promising leads for experimentally investigating the processes by which people acquire knowledge in a form useful for comprehending subsequent events.

F. The Lessick-Hannigan Paradigm.

Hannigan's research (1976, and see Bransford & Nitsch, in press) represents an attempt to incorporate preceding chapter discussions into a workable experimental paradigm. Three lines of thought contributed to the research project: (1) Differences between problems of learning and remembering (Bransford, McCarrell, Franks, & Nitsch, in press; Bransford & Franks, 1976; Bransford, Franks, & Nitsch, in press); (2) Analyses of comprehension flexibility and problems of understood meaning (Barclay, Bransford, Franks, McCarrell, & Nitsch, 1974; Bransford, McCarrell, & Nitsch, 1976; Bransford, McCarrell, Franks, & Nitsch, in press; Hannigan, 1975; Nitsch, 1975), (3) Discussion of the development of expertise as involving a "remodeling" of the system that allows one to more directly apprehend subsequent information (e.g., Bransford, Nitsch, & Franks, in press; de Groot, 1965; 1966). Hannigan's research explores conditions necessary for acquiring information in a form that permits people to transfer to new inputs. In particular, her main measure involves the effects of particular experiences on subjects' abilities to more directly apprehend novel sentences by determining the degree to which subjects could detect each of a number of different sentence types in white noise.

Group I in Hannigan's study (the No-Framework Group) heard a list of seventy sentences and were asked to rate them on ease of comprehension. Examples of her acquisition sentences are as follows: The man set up housekeeping in the airplane; The man threw the curtain over the metal bar; The man propped the door against the rock wall; The man thrashed the leaves with his cane; The man put the chair at the base of the tree; The man piled the bricks under the tree; The man opened his briefcase; The man turned the bell upside down; The man made a sack out of the sheet. All of these sentences are understandable in isolation. Indeed, Hannigan's subjects rated them as very easy to comprehend.

The subjects in Group II (the Framework Group) heard the identical set of seventy acquisition sentences. However, they were asked to understand each sentence as a description of "Survival on a deserted island" and also as an illustration of one of seven particular aspects (sub-categories) of survival (e.g., "Making shelter"). The subjects were instructed to imagine that anything mentioned in a sentence was actually on the island, so ratings of comprehensibility should simply indicate their ability to see how a certain activity could be related to a particular sub-topic. The examples and particular sub-topics are as follows: Making a shelter. The man set up housekeeping in the airplane; The man threw the curtain over the metal bar; The man propped the door against the rock wall. Reaching for food on a branch above your head. The man thrashed the leaves with his cane; The man put the chair at the base of the tree; The man piled the bricks under the tree. A container for carrying food. The man opened his briefcase; The man turned the bell upside down; The man made a sack out of the sheet.

Understanding the preceding sentences from the perspective of survival clearly influences one's comprehension of them. This illustrates the effects of situations on the comprehension of subsequent inputs, yet inputs further clarify initial perspectives as well. In order to investigate the degree to which examples can further clarify initial concepts or schemas, Hannigan included a third group in her study, the Framework-After Group. These subjects heard all seventy sentences without any topic or sup-topics (like the No-Framework subjects). They were told about the "survival" topic and sub-topics immediately after sentences acquisition (prior to testing). If comprehending the examples provided further clarification for the initial concept, the Framework-After procedure should not provide sufficient opportunity for subjects to move beyond their normative knowledge of survival (and its seven sub-categories). These subjects should therefore perform less adequately than the Framework Group.

Following acquisition Hannigan compared the performance of subjects in the No-Framework, Framework, and Framework-After conditions. As a test, she took advantage of the finding that meaningful sentences are better identified under conditions of white noise than are less meaningful sentences (Miller, Heise, & Lichten, 1951; Barclay, personal communication). She reasoned that subjects in the Framework Group should now be able to understand novel but appropriate sentences which deal with aspects of survival (for example, The man got up on the box). If these sentences were, in fact, more meaningful for the Framework Group then they should be better detected in white noise.

During the test, all subjects heard the same sentences embedded in white noise. Their performance was compared to a Baseline Group which received no initial experimental inputs prior to the detection test. Test sentences included OLDS (those heard by all groups except Baseline), Novel Appropriates (appropriate means can be seen as related to the previous survival theme) and Novel Inappropriates (inappropriate means not readily seen as related to the survival theme). For example, The man put the eraser under the table was a Novel Inappropriate. The subjects' task was to listen to each sentence embedded in white noise and attempt to repeat it aloud as best they could.

For OLD sentences, accuracy of repetition in the No-Framework, Framework, and Framework-After Groups was superior to the Baseline Group. (The Framework Group was better on OLDS than were the other two groups.) All three groups were equivalent to the Baseline subjects on the Novel Inappropriate sentences. However, the most important data involved performance on the Novel Appropriate test sentences. On these, the No-Framework and Framework-After Groups were no better than the Baseline Group. In contrast, the Framework Group performed much more accurately at repeating the Novel Appropriate sentences. The subjects in this group were slightly less accurate on these than on OLDS. Nevertheless, the Framework Group was as accurate on Novel Appropriates as the No-Framework Group was on OLDS.

Subsequent experiments revealed that subjects in the No-Framework and Framework-After Groups exhibited excellent recognition memory for the OLD sentences (tested without white noise). They had not simply failed to learn

the inputs. However, the mere accumulation of inputs does not necessarily allow one a degree of clarity sufficient to understand something in a new way at a later point in time.

Hannigan also explored the degree to which the Framework Group's ability to transfer to Novel Appropriate sentences in white noise depended on "making contact" with related "stored" acquisition sentences. For example, the subjects may have originally heard The man propped the door against the wall as an example of "Making shelter" during acquisition. The Novel Appropriate sentence The man leaned the car hood against the tree is more similar to this acquisition sentence than any other. Thus even other "Making shelter" sentences involve different types of relations (e.g., throwing a curtain over a metal box, setting up housekeeping in an airplane) which are more similar to other Novel Appropriates.

Hannigan reasoned that if transfer to a Novel Appropriate depended on "making contact" with a similar acquisition sentence, there should be strong dependencies between subjects' abilities to detect a particular acquisition sentence (an OLD) and its Novel Appropriate counterpart. Her analyses revealed no such dependencies, suggesting that "memory mediation" was not the basis for transfer. This is not particularly surprising, since one must interpret the Novel Appropriate sentences in a specific manner in order to adequately perceive their similarity to the acquisition sentences. The No-Framework Group subjects showed no transfer, yet received identical Acquisition Sentence-Novel Appropriate counterparts. The ability to comprehend Novel Appropriate sentences in a particular manner is presumably what was learned by the Framework subjects. This apparently provided the basis for transfer; not "contact" with stored acquisition sentences.

G. The "Coming to Understand Things We Could not Previously Understand" chapter.

Bransford and Nitsch (in press) build from the previously mentioned chapters and research in an attempt to look directly at problems faced by educators and clinics. They ask how can we help people come to understand things they could not previously understand (or come to understand things in new ways)? The chapter proposes an abductive (rather than inductive or deductive) framework for conceptualizing growth, and contrasts this with traditional conceptions of learning as the formation of "concept-referent associations," etc. The abductive approach stresses that one not only learns from experience, one learns to experience. One's momentary situation or perspective affects how inputs are experienced, which determines what is learned from the experience. The reciprocal influences of situation on input (assimilation) and input on situation (accommodation) are assumed to lead to a remodeling or redefinition of one's current perspective so that subsequent inputs can now be understood (and learned from) in new ways. The schematization is therefore neither solely empiricistic nor rationalistic. It is neither solely deductive nor inductive, but perhaps more equivalent to Peirce's (1932) notion of abduction. The schema highlights the relatively gradual, "bootstrapping" nature of the growth process, and focuses attention on the situational support necessary

in order to effectively learn from exposure, practice, etc. It also directs attention to questions about the nature of the changes in the system that permit transfer to occur.

Relevant data from the adult as well as child comprehension literature is reviewed and discussed in terms of this abductive framework. Experiments by Pollchik (1975) as well as Hannigan (1976) are utilized as illustrations of abduction. Subsequent studies currently being conducted by Nitsch on the "context derived" nature of knowing are also discussed.

The chapter suggests potentials for improving existing means of instruction (e.g., flash card techniques) as well as reconsideration of traditional normatively-based procedures for assessment and intervenation. Supporting evidence from the existing experimental literature on comprehension and language acquisition is also discussed. This chapter probably represents the best assessment of where we are at the end of this three-year NIE granting period (especially when contrasted with our initial grant application). In addition, this chapter suggests some of the directions for our future research.

IV. Assessment of our current position and potential educational applications

In order to more clearly describe our current position, in this section we outline a series of contrasts between this position and several alternative approaches to issues relevant to education. We then give a brief indication of potential educational applications of our position. (Some of the discussion in both parts of the present section are adapted from our recently submitted grant application to NIE, June, 1976.)

A. Contrasts with other theoretical positions.

(1) Research on episodic memory. Tulving (1972) questions whether research on episodic memory is directly related to education. Our present perspective also reflects this concern by stressing that growth and subsequent transfer are not simply a function of the acquisition of stored content. Subjects in a memory study may acquire a list of facts, but be unable to perform adequately on a transfer task. Furthermore, transfer may not be "mediated" by contact with stored episodic traces (cf. Hannigan, 1976).

(2) Research on "depth of processing" and "imaging." It seems clear that how one acts upon inputs (including imaging them) affects remembering (e.g., Craik & Lockhart, 1972; Craik & Tulving, 1975; Jenkins, 1971; Postman, 1975). However, we are interested in the degree to which certain acts promote the development of flexible decontextualized knowledge that facilitates transfer rather than memory. Some of our research has investigated whether certain types of activities result in a remodeling which can decrease subjects' abilities to remember specific inputs, yet facilitate transfer. Subsequent studies will explore whether attempts to explicitly remember may sometimes interfere with remodeling and hence hinder sebsequent transfer.

(3) Research on encoding specificity. The notion of the development of flexible decontextualized knowledge is related to assumptions about encoding specificity (see Tulving & Thomson, 1973). However, our investigations stress those processes that free someone from the need for explicit contextual support so that transfer can more readily occur. If one were to employ Tulving's (1972)

terminology, the focus is on how one moves from context-specific "episodic" memory to more general "semantic" memory. However, we do not assume that two separate "memories" are involved.

(4) Research on semantic memory. Studies of semantic memory (e.g., Collins & Quillian, 1969; Freedman & Loftus, 1971; Loftus & Freedman, 1972; Meyer & Ellis, 1970; Meyer & Schvaneveldt. 1971; Rips, Shoben, & Smith, 1973; Smith, Shoben, & Rips, 1974) provide relevant information from their investigations of the products of previous growth and learning. In contrast to this approach, however, much of our research is aimed at clarifying the processes of acquiring knowledge in useful forms. Furthermore, we do not view semantic memory as an interconnected "list" of stored products; i.e., concepts, meanings, etc. We investigate the development of decontextualized knowledge that permits transfer and attempt to contrast this orientation to those that view "semantic memory" as lists of stored products.

(5) Computer models of knowledge. One aspect of the work on computer models of knowledge (cf. Schank, 1972; Rumelhart, Lindsey, & Norman, 1972; Winograd, 1971; Minsky, 1975; etc.) is the attempt to characterize what must be known in order to carry out certain acts of understanding. Our approach, however, is more oriented to how this knowledge is acquired and how it may change. For example, Rumelhart and Ortony (in press) provide a helpful analysis of a schema approach to knowledge, yet are reduced to postulating "frequency" and "utility" as principles for schema acquisition. Our approach suggests that such learning concepts are inadequate for understanding the processes by which one can acquire knowledge in a form useful for clarifying subsequent events.

(6) Studies of text processing. Research by Kintsch, 1974; Frederickson, 1972, 1975; Meyer, in press; Van dijk, 1973, etc., investigate relatively invariant structures that affect prose comprehension. Our orientation differs from these in a number of ways. In addition to our emphasis on transfer rather than remembering, we focus on the relationship between a particular text structure and the knowledge of the reader-comprehender. From the present perspective, notions of "optimal text structure" must be defined relative to the nature of the reader and the purposes for which information is to be used. Indeed Bransford & Nitsch (in press) report a study illustrating that different experiences prior to reading a text had powerful effects on comprehension and transfer. We therefore focus on the nature of the skills and knowledge a reader might currently have that permits him to make optimal use of various structures of text.

Current representations of text "meaning" (e.g., Kintsch, 1974; Meyer, in press) are not necessarily geared to consider the types of growth or remodeling that take place while reading texts. Texts frequently contain examples, yet text grammars simply represent these as propositions stored in semantic memory. One must then assume that this representation is "contacted" in order to mediate transfer. Our initial studies (cf. Bransford & Nitsch, in press; Hannigan, 1976) raise strong doubts about such assumptions, and our attempts to contrast "remodeling" with the "accumulation of stored contents" (including propositions) represents a potential, alternate point of view.

(7) Research on adjunct aids to learning. Research by Rothkopf (1966, 1972) is relevant because it deals with ways to facilitate prose comprehension. However, as Anderson and Biddle (1975) note, this area is plagued by a lack of a theoretical perspective. For example, studies of the effects of embedded questions are frequently carried out without careful regard for the nature of the questions nor their relationship to the particular texts used. From the present perspective, the effectiveness of any input like an embedded question must be evaluated relative to the comprehender's momentary "situation." Indeed, the study by Pollchik (1975) revealed that slight changes in texts can interact strongly with the effectiveness of embedded questions. The present orientation focuses on the usefulness of certain instructional techniques as a function of the comprehender's particular "situation" at a given point in time.

(8) Research on learning goals. Research by Rothkopf and Billington (1975) focuses on how certain well-specified goals can facilitate acquisition. However, such studies have invariably utilized goals that simply guide readers to acquire certain types of factual content, and the emphasis is on recall rather than transfer. From the present perspective, goals couched in terms of a meaningful problem or a related task can help structure in the comprehender a "situation that permits factual content to be better understood (rather than simply memorized), hence more remodeling and subsequent transfer are likely to take place. Indeed, the optimal "text structures" in Meyer's (in press) studies are ones that begin with an intuitive, problem-oriented perspective. Our emphasis is on ways to "set the stage" so that more meaningful learning can take place. We also assume that increasing the number of sub-goals one has need not detract from learning (in contrast to research reported by Rothkopf & Billington, 1975) if the goals are interrelated rather than unrelated as in previous studies.

(9) Research on automatization. Research by Chase and Simon (1973), Laberge and Samuels (1974), and Kohlers (1975) deals with the development of expertise. Chase and Simon (1973) conclude that practice is the major variable underlying skill learning. While this is undoubtedly true in some sense, it tells us nothing about the conditions necessary in order to make exposures maximally effective. Our research is directly related to this latter question.

(10) Previous studies on reading. Studies of reading skills and comprehension ranging from Huey (1908) to Gibson and Levin (1975) supply valuable information about differences between skilled and non-skilled readers. Our focus is on the process of gaining various skills. Our approach assumes that optimal instructional techniques are relative to the learner's momentary cognitive-perceptual situation. The focus is on the problem of taking one beyond his current state of knowing or understanding.

B. Potential educational applications.

The primary thrust of our recent investigations has been to examine processes which help the comprehender move beyond his current ability to understand linguistic materials and to explore the nature of the changes in his knowledge that may then permit transfer to other domains. Obviously, the specific procedures employed to facilitate growth depend upon one's initial level of expertise. However, we believe that there are certain invariant

processes which are involved regardless of level of expertise; especially the development of the ability to comprehend in relatively decontextualized settings and the notion of the internal support system that promotes such acts of comprehension. Our goal is to frame an adequate characterization of the effects of the growth process on one's support system and how this remodeling allows one to comprehend in decontextualized situations.

This goal may be restated in terms of an attempt to provide the resources required to answer the question: How can we teach so that we encourage the acquisition of knowledge in a usable, decontextualized form? As corollaries to experimental research, we have begun to seek further information about the growth process and the methods good teachers intuitively use to promote this growth in their students from sources such as: (1) In vivo studies of growth and remodeling resulting from various uses of textual materials in teaching college students; (2) Interviews with consultants who have extensive experience as elementary school teachers; (3) Evaluation of instructional materials currently used in the curriculum of elementary schools. These sources of insight are being incorporated into our theorizing about the relationship between growth processes and the nature of the remodeling which takes place in the system. An understanding of these remodeling processes is necessary in order to know what to ask about, for example, in reading and comprehension skills or even to know how to test and what to test for in evaluating the comprehension of written and oral linguistic materials. Furthermore, our emphasis on the remodeling aspects of growth suggests implications for structuring teaching techniques and evaluating their effectiveness. Instead of compiling a list of facts or techniques, we need to stress understanding why particular techniques work; how these techniques are instrumental in inducing or facilitating growth. Once again we realize that by first attempting to characterize the nature of the growth process per se, we will be in a better position to know how to generate the most effective means of teaching <u>given</u> a particular student's present situation.

The basic orientation of our research hinges upon the <u>reciprocal</u> nature of situation-input relationships in any comprehension situation. Both one's ability to bring to bear the relevant aspects of his own knowledge (i.e., his current situation) and his ability to know what activities to perform when seeking additional clarification for any particular input can be manipulated in order to facilitate growth and maximize the potential for future transfer. This perspective leads us to make several tentative suggestions about how one might optimally structure situation-input relationships, for example, with beginning readers. Perhaps we should first help children to come to understand some situation and then teach them basic reading skills in that context. By providing experiences designed to explicitly map into and extend or elaborate upon their current knowledge, the acquired information can then be more <u>directly</u> useful in learning to read. For example, instead of using flash card drills in the conventional manner (which encourages an attitude more similar to "word calling" than to comprehending), perhaps one might require not only that each word be identified but also ask whether it could be appropriately used in some specific context. (For instance, students could be asked to judge whether each word would be appropriate on a picnic.) Situational support can make the recognition of a word an activity which is related to the purpose of an overall

theme or topic--just as is the case when one is actually reading from a text. By varying the contextual settings, students might be helped to develop a flexible ability to use what they know.

Our concern with the process of moving beyond one's current level of understanding or expertise also demands a sensitivity to certain characteristics of inputs which can facilitate this growth. Even in the case of fledgling readers in the middle elementary school years, such a consideration seems crucial to evaluating the appropriateness and effectiveness of the reading materials they encounter. An input which deals only with a description of the mundane and totally familiar (relative to the reader/comprehender's current knowledge) provides little opportunity or incentive for growth and remodeling. More effective inputs would seem to be materials which deliberately require one to go beyond his current level of understanding to incorporate new information or a new perspective on familiar information. For example, even though a student has mastered the rudimentary mechanical skills associated with reading, he still needs experiences which promote the development of expertise in extracting information from textual materials. A text which simply provides a description of facts is neither optimal for this pedagogical purpose nor is it appealing from the reader's standpoint. We surmise that texts which are structured to require a student to understand the significance of an input (rather than simply understand it as a factual description) would also be more effective in facilitating later transfer to related domains. This "bootstrapping" process of using the reader's knowledge as a starting point but requiring him to go beyond this level of understanding represents an important criterion to be used in evaluating both texts designed especially for reading instruction and those used for other subject areas.

Finally, in considering the growth process, we reemphasize the importance of the activities that help one clarify both his present situation and the inputs with which he is dealing. These activities are an integral part of the growth process, but it must be realized that no single activity is optimal for clarifying one's situation with respect to all potential inputs. The appropriateness of an activity is also determined relative to the anticipated uses to which the knowledge may subsequently be put (i.e., to the nature of the transfer task anticipated). For example, in Hannigan's studies, the activity of comprehending the acquisition sentences for the Framework Group permitted relatively accurate detection of these sentences in white noise, but had a different transfer task been required, perhaps another activity at acquisition would have been more appropriate. We do not believe it fruitful to attempt to create a taxonomy of all possible activities one might adopt to clarify his situation (and thus better understand some input). Instead we have stressed understanding how a particular activity can influence the nature of the growth and remodeling of one's knowledge and thereby determine his subsequent ability to use this knowledge in other domains.

V. Overall Summary and Conclusions

Many individuals have questioned the adequacy of basic psychological

theories for providing insights into problems of education. We believe that this is a valid matter for concern. Indeed many theories based on current research in experimental psychology are not directly oriented toward problems faced by educators. In particular, research and theories concerning episodic memory, semantic memory, and verbal learning do not necessarily address the crucial problems involved with understanding psychological growth. Our attempts to avoid committing such an oversight have focused on the problems of growth. Our discussion has been couched in terms of understanding how people become and remain experts. The problem of learning what to do to go beyond one's current state of clarity and understanding was stressed. Growth could be represented by detailing the products of different states of understanding. However, this ignores the crucial problem of which acts of knowing or clarification must be performed in order to get from one state to the next. In the context of education, helping students learn what to do in order to achieve greater clarity and understanding seems much more important than the mere transmission of content. Content can quickly become obsolete. In contrast, the ability to know what one needs to do to clarify and further his present understanding of this content never becomes stale or static. This ability helps one continually grow.

Can a theoretical and empirical emphasis on experts help reduce the gap between education and basic psychological research? At one level, a positive answer to this question might seem doubtful. Since practice and exposure appear to be major variables that influence acquisition, there may be very little one could say except "Go practice." However, the present approach has raised additional questions. For example, it has been demonstrated that equivalent exposures do not necessarily result in equivalent acquisition of information (e.g., the x-scanning study). Students must be helped to make exposures work. In short, an exposure is not an exposure is not an exposure. The effects of exposure depend on the current framework for articulating the significance of inputs. For example, exposure to chess positions would have little positive effect unless an individual had some understanding of the nature of chess. Similarily, students who are exposed to a list of examples will be less able to use this information in a new situation if they initially had no idea of what the examples were supposed to illustrate. As a related illustration, consider the notion of exposure in learning a language. It is extremely doubtful that children could learn a language simply by being exposed to it spoken over a tape recorder in a dark, contextless environment. Without perceptual support from the context of natural world artifacts and actions, children would have no framework for articulating the significance of these utterances, and hence for understanding linguistic meaning and cracking aspects of the syntactic code (e.g., see MacNamara,1972; Nelson, 1974).

We have argued that a basic problem of education is to help students learn what to do to make exposures meaningful. Effective teachers use a variety of intuitively based techniques for helping students perform such acts of knowing: They prompt students to ask and answer particular questions, they relate novel inputs to already acquired information by way of analogy, they provide both positive and negative examples to help clarify points. Despite the important role of such activities, they remain intuitively based. Ideally, theoretical psychology should provide a framework that helps clarify what is

happening when one chooses to prompt certain acts of knowing. Such a framework could help teachers understand the growth process so that they could continually clarify, evaluate, and go beyond their momentary levels of expertise.

Unfortunately, theoretical psychology fails to provide a coherent framework suitable for understanding the growth process. For example, theories of episodic remembering certainly do not perform this function. They may be useful for understanding questions such as "Why are students better able to recall concrete examples than abstract principles?", but they fail to clarify the process by which students learn what the examples are examples of. Similarly, theories of semantic memory fail to provide insight into the growth process. Rather than focus on the processes of acquisition, their major orientation aims toward predicting the speed and ease of knowing given that one had already acquired information in a certain form.

As a step toward developing a framework for clarifying the growth process, we have suggested that the development of expertise must involve something more than the mere accumulation of more and more content. Growth appears to involve a remodeling of one's perspective that enables one to "see" differently. Such remodeling involves developing a more global, abstract framework that one acts in terms of and that sets the stage for clarifying subsequent experiences. In short our present orientation places a primary emphasis on transfer rather than on one's ability to recall what was learned.

In summary, our overall question is similar to that stated in our original grant proposal to NIE: "How do we help people move beyond their current, normative state of knowing and understanding?" If people are presented with information that reaches too far beyond their current state of "readiness," they will quickly become lost and be unable to learn from the material (cf. Bransford & Nitsch, in press). On the other hand, information that completely maps into learner's momentary, normative knowledge will not facilitate growth--it will not help them move beyond their current state of knowing. Furthermore, they will be deprived of the inherent excitement that novelty and discovery entails (Bransford & Nitsch, in press).

Despite this global similarity between the initial grant proposal and our present theoretical position, we feel that we have made considerable progress. In particular, we believe that our current focus on problems of growth and transfer is much more sophisticated and potentially fruitful than were our initial ideas as presented in the original NIE grant proposal. In addition, newly developed and emerging experimental paradigms (e.g., see Pollchik, 1975; Hannigan, 1976; Bransford & Nitsch, in press) provide the promise of new insights into the growth of knowledge, as well as educational procedures that can facilitate such growth. These are experimental paradigms which focus on issues not necessarily being studied by many psychologists and educational investigators. Several studies are underway to explore these growth processes in more detail (see Bransford & Nitsch, in press).

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Hannigan, M. L. The effects of frameworks on sentence perception and memory.

Nesbitt, J. G. Memory for nouns from similes as a function of ease of comprehension: An investigation of some interactions among memory measures.

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Figures

Figure 1 (a) & (b): Two different acquisition conditions.

Figure 2: Test condition for Figure 1(a) & (b).

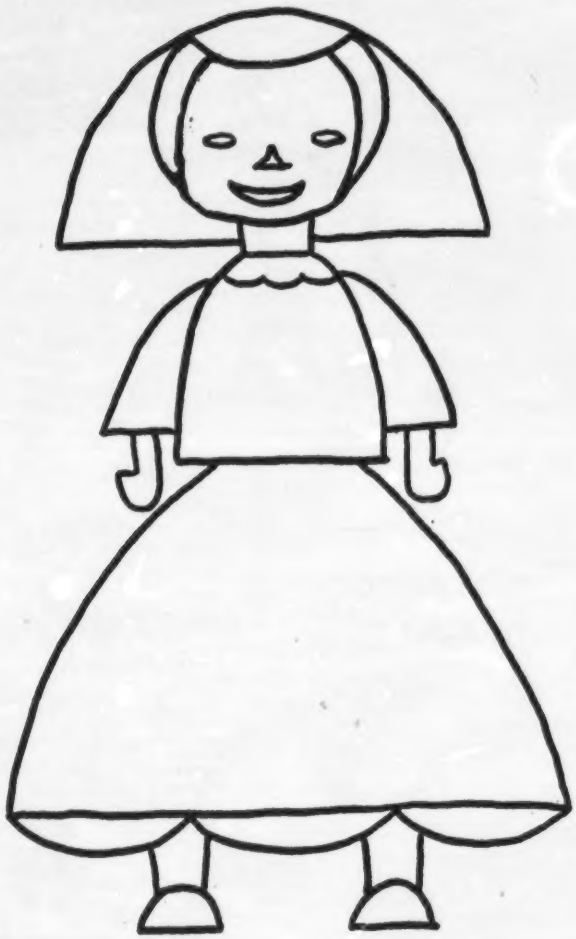

Figure 1(a)

Figure 1(b)

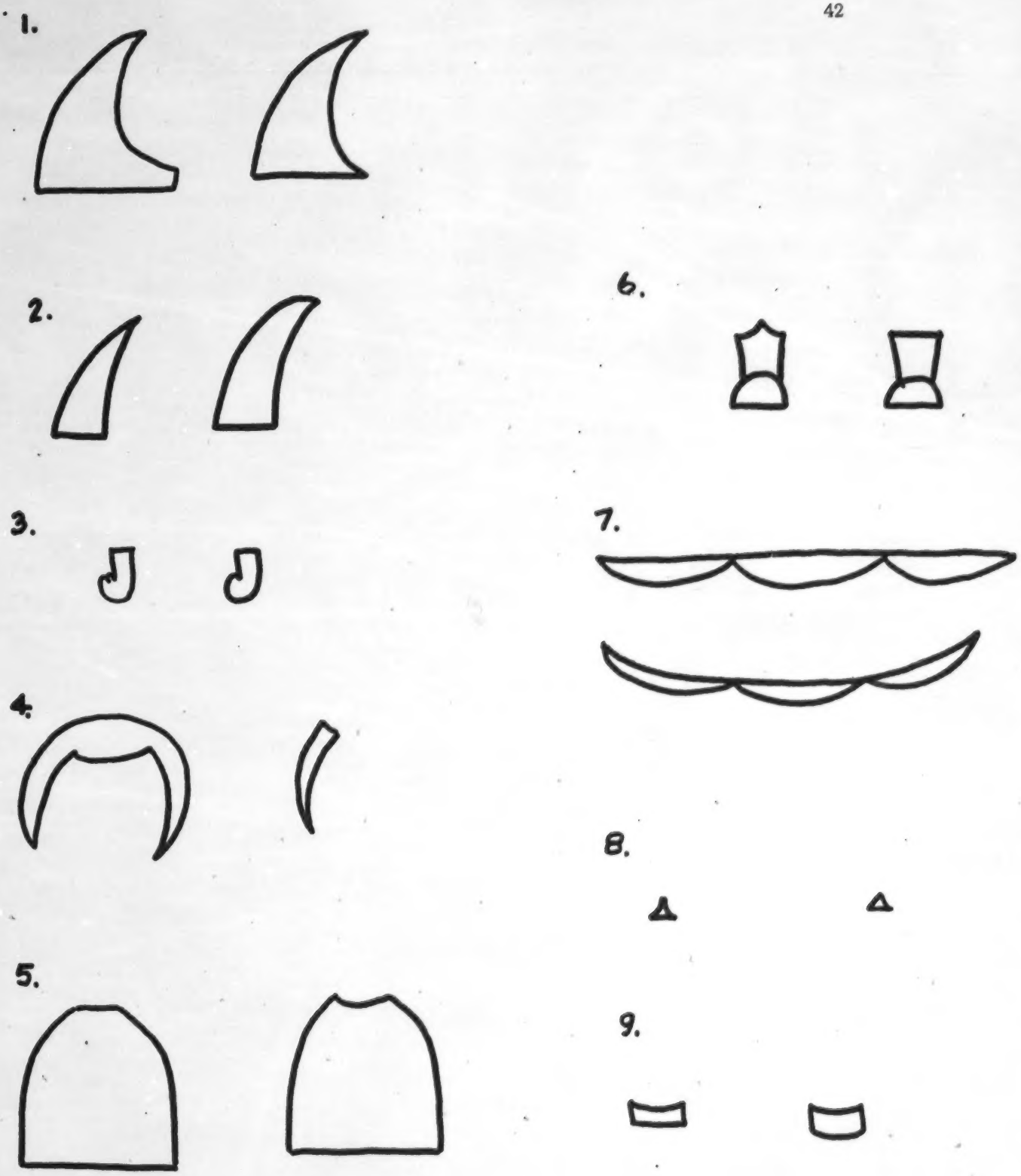

Figure 2